The Temporal Changes of Tissue Oxygen Saturation (StO_2) and Central Venous Oxygen Saturation ($ScvO_2$) During Sepsis/Septic Shock Resuscitation

Chairat Permpikul MD*,
Chutima Cheranakhorn MD*

** Division of Critical Care, Department of Medicine, Faculty of Medicine, Siriraj Hospital, Mahidol University, Bangkok, Thailand*

Background: *Restoration of adequate tissue oxygenation is the goal of shock resuscitation. Commonly, central venous oxygen saturation and lactate clearance are used to monitor this therapeutic endpoint in sepsis. Tissue oxygen saturation (StO_2) obtained by near-infrared spectroscopy (NIRS) has been introduced as an alternative.*

Objective: *To determine the temporal changes of tissue oxygen saturationand central venous oxygen saturation ($ScvO_2$) in severe sepsis/septic shock patients from initial resuscitation to 72 hours after treatment, and to explore the relationship between both parameters including the association with outcomes.*

Material and Method: *A prospective, observational study was performed in a single center 14-bed university hospital, Medical Intensive Care Unit. The present study enrolled severe sepsis/septic shock patients aged >18 years. Central venous oxygen saturation and tissue oxygen saturation were measured at 0-1st hour (right after central venous catheter was placed), 1st-6th hour (the point when hemodynamic goal was achieved), 6th-9th hour, 9th-12th hour, 24th hour, 48th hour, and 72th hour in simultaneous fashion.*

Results: *Thirty-five patients were enrolled and 170 paired-measurements were made. During the first 24 hours, both tissue and central venous oxygen saturation gradually increased in the same direction. However, only fair correlation was observed ($r = 0.253$, $p = 0.01$) and the agreement was not satisfactory. Mean StO_2 during the first 24 hours was higher in survived patients ($(82.6 \pm 9.3$ vs. 74.3 ± 16.0, $p = 0.016$). When partitioned $ScvO_2$ into ranges, namely $ScvO_2$ <60%, 60-64%, 65-69%, 70-74%, 75-79%, 80-84% and >85%, the corresponding StO_2 values were found randomly throughout the $ScvO_2$ ranges, without specific predilection.*

Conclusion: *The temporal changes of StO_2 and $ScvO_2$ during sepsis/septic shock resuscitation were demonstrated. Their correlation and agreement were not satisfactory. No specific StO_2 value for the reversal of tissue hypoxia was observed. More studies are needed to explore the benefit of StO_2 as a bedside tool for tissue perfusion monitoring.*

Keywords: *Tissue oxygen saturation, StO_2, Central venous oxygen saturation, Near-infrared spectroscopy, NIRS, Severe sepsis, Septic shock*

J Med Assoc Thai 2014; 97 (Suppl. 3): S168-S175
Full text. e-Journal: *http://www.jmatonline.com*

The pathophysiologic basis of septic shock consists of the alteration in macro and microcirculatory systems as well as cardiac dysfunction, resulting in tissue hypoxia and organ failure[1,2]. The concept of rapid restoration of tissue perfusion or early goal-directed therapy (EGDT) is proven to improve treatment outcomes[3]. Central venous oxygen saturation ($ScvO_2$) or serum lactate are recommended to identify the resuscitation end point at which the tissue perfusion is restored. However, various surveys revealed that venous oxygenation was not monitored in a significant proportion of patients. This was partly due to the lack of skill, experience, and equipment[4,5]. In addition, later studies disclosed no relationship between central venous oxygenation and serum lactate during septic shock resuscitation[6]. Thus, the real-time, non-invasive monitoring of tissue oxygenation at bedside, if reliable and obtainable, will help guide management of severe sepsis/septic shock resuscitation[7].

Near-infrared spectroscopy (NIRS) technology has been used as a tool to monitor tissue oxygen saturation (StO_2) in various acutelyill patients. The

Correspondence to:
Permpikul C, Division of Critical Care, Department of Medicine, Faculty of Medicine, Siriraj Hospital, Mahidol University, Bangkok 10700, Thailand.
Phone: 0-2419-8534, Fax: 0-2419-8537
E-mail: chairat.per@mahidol.ac.th

technical concept involves the uses of differential absorption properties of oxygenated and deoxygenated hemoglobin to evaluate skeletal muscle oxygenation. Near-infrared light (680-800 nm) easily crosses biological tissues, which have a low absorption power, and is absorbed only by hemoglobin, myoglobin, and oxidized cytochrome[8]. The NIRS signal is limited to vessels with diameter below 1 mm (arterioles, capillaries and venules). Therefore, StO_2 is postulated to be a reflection of the micro-vascularoxygenation[9].

The relationship of StO_2 and $ScvO_2$ in septic shock patients is not well defined[10-12]. Most studies used a single point correlation in different phases of disease[13,14], which might represent different pathophysiologic process, both from diseases and treatment. None of the studies demonstrated temporal change of StO_2 during resuscitation. The purposes of this study were to determine the dynamics of StO_2 during septic shock resuscitation, from the beginning to 72 hours. Also we aimed to observe the relationship between StO_2 and $ScvO_2$ in these patients, and to explore the cutoff point at which tissue perfusion was restored.

Material and Method

A prospective, observational study was performed in a single center 14-bed university hospital, medical intensive care unit. The present study protocol was approved by the Hospital Ethics Committee. Each patient or the patient's relative provided written informed consent.

Patients

Patients were eligible for inclusion if they were older than 18 years of age, had severe sepsis or septic shock defined according to the SCCM/ESICM/ACCP/ATS/SIS International Sepsis Definitions Conference[15], and were admitted to the ICU within 24 hours of the onset of severe sepsis/septic shock. Patients were excluded if they met any of the following criteria: 1) terminal illness, 2) pregnancy, 3) absolute contraindication for central venous catheterization, or 4) primary diagnosis of acute coronary syndrome, acute cardiogenic shock, acute cerebrovascular event, or active gastrointestinal bleeding.

Tissue oxygen measurement equipment

Tissue oxygen saturation (StO_2) was measured by the portable In Spectra StO_2 tissue oxygen monitor, Model 650 (Hutchinson Technology Inc. Hutchinson, Minnesota, USA). This equipment measured tissue absorbance values between 680-800 nm, and used probe spacing of 15 mm, which received StO_2 at 14 mm of depth. A light-scattering calibrator was used to normalize the tissue spectrometer during startup of the system and before each measurement. Sample measurement signals were updated every 3.5 seconds. The NIRS probe was placed on the patient's thenar eminence. After at least 1 minute of signal stabilization, the StO2 was measured.

Study protocol

After the patients were enrolled, they underwent treatment in accordance with the institute's septic shock management guidelines. Briefly, isotonic crystalloid was rapidly given at rate 10-20 ml/kg during the first half hour and additional bolus were given to raise mean arterial pressure toward 65 mmHg. A central venous catheter (CVC) was inserted after 1,000-2,000 ml fluid in order to monitor central venous pressure (CVP) and to perform fluid challenge. Norepinephrine was administered to increase blood pressure when adequate intravascular volume was achieved as judged by a CVP of 8-12 mmHg. When the target blood pressure was reached, central venous blood was sent for $ScvO_2$. Dobutamine infusion was added in patients who had venous oxygen saturation less than 70% and a hematocrit of more than 30%. For venous hypoxia patients with hematocrit less than 30% red blood cell transfusion would be given. All patients received appropriate empirical antibiotics, which in some cases were later adjusted according to the culture results.

According to the protocol, StO_2 and $ScvO_2$ were simultaneously measured as soon as the central venous catheter was inserted. The following measurements were obtained at 1) hour 1^{st}-6^{th} or at therapeutic goal achievement, 2) hour 6^{th}-9^{th}, 3) hour 9^{th}-12^{th}, 4) hour 24^{th}, 5) hour 48^{th} and 6) hour 72^{th}. Each patient had to have at least three data sets. The information collected at enrollment included demographic characteristics such as age, sex, co-morbid disease, APACHE) II score, SAP II score, primary site and type of infection. All patients were followed during the first 72 hours.

Statistical analysis

A descriptive analysis was performed. Discrete variables were expressed as counts (percentage) and continuous variables as mean $\pm$ standard deviation (SD). Differences between group means were tested by Student t-test. For non-normal distribution, differences were tested by a non-parametric test. The

correlation between StO_2 and $ScvO_2$ was determined by using Pearson's correlation test; Bland-Altman plot was used for the agreement. Statistical significance was defined as $p<0.05$ (two-tailed test). Using an α of 0.01, power of 0.9, null correlation of 0.0 and expected correlation of 0.3; the sample size was 159 paired-measurements.

Ethical considerations

The present study was reviewed and approved by the Siriraj ethics committee, using the Declaration of Helsinki.

Results

Thirty-five patients were enrolled, resulting in a total of 170 $ScvO_2$ and StO_2 paired measurements. Twenty patients (57%) were male. The mean age was 61±14 years and the mean APACHEII score was 25.3± 8.0. Six of these patients (17.1%) had severe sepsis and twenty-nine (82.9%) had septic shock. The most common source of infection was the urinary tract (28.6%), followed by the respiratory tract (17.1%), skin and soft tissue (14.3%), primary septicemia (8.6%), the gastrointestinal tract (5.7%) and other sources (5.7%). Two patients (5.7%) had febrile neutropenia and four patients (11.4%) had sepsis from unknown sources.

Only 13 (37%) of the patients achieved the therapeutic goal within 6 hours while 20 (71.4%) and 30 (85.7%) reached the goal within 12 hours and 24 hours respectively. The ICU mortality rate was 22.9% and 28 days mortality was 31.4%. Clinical characteristics were summarized in Table 1.

The temporal changes during resuscitation of StO_2 and $ScvO_2$ during the first 72 hours are demonstrated in Fig. 1. Both parameters changed in the same fashion, reaching their maximum during the

Table1. Patient characteristics

Patients (pairs of measurement)	35 (170)
Age (years, mean ± SD)	64±14
Male n (%)	20 (57)
BMI (kg/m^2)	22.2±4
Underlying diseases n (%)	
DM	13 (37.1)
Hypertension	14 (40)
Chronic renal failure	5 (14.3)
Cirrhosis	6 (17.1)
Coronary disease	5 (14.2)
Previous stroke	7 (20)
Immunosuppression/immunocompromised	5 (14.2)
Cancer	4 (11.4)
Dyslipidemia	11 (31.4)
Severity scores	
APACHE II	25.3±8
SAP II	51.4±14.9
Primary site of infection n (%)	
Urinary tract	10 (28.6)
Respiratory tract	6 (17.1)
Skin and soft tissue	5 (14.3)
Septicemia	3 (8.6)
Abdomen	2 (5.7)
Febrile neutropenia	2 (5.7)
Other	2 (5.7)
unknown	4 (11.4)
Organ failure n (%)	
ARDS	20 (57.1)
Mechanical ventilation	21 (60)
Acute kidney injury	22 (61.9)
Renal replacement therapy	8 (22.9)
DIC	14 (40)

6^{th}-9^{th} hours. While these values were parallel, the mean tissue oxygen saturations in each sampling were approximately 15% higher than the venous counterparts. When grouping patients into survivors and non-survivors groups (Fig. 2), no significant differences in minimal StO_2 (83.4±7.8 vs. 67.4±16.7, p = 0.105) and maximal StO_2 (86.7±6.9 vs. 83.9±10.3, p = 0.379) were demonstrated. However, the mean StO_2 in the survivor group was significant higher (82.6±9.3 vs. 74.3±16.0, p = 0.016).

To examine whether there was any cut off value for StO_2 to signify $ScvO_2$ of 70%, we partitioned $ScvO_2$ into ranges (Fig. 3), namely $ScvO_2$ <60%, 60-64%, 65-69%, 70-74%, 75-79%, 80-84% and >85%. The mean values of tissue oxygen saturation were found randomly throughout the $ScvO_2$ ranges, without specific predilection.

Fig. 4A demonstrates the correlation between StO_2 and $ScvO_2$, which was statistically significant (p 0.01), with r = 0.253. The average of each pair of StO_2 and $ScvO_2$ was plotted against their differences (Bland-Altman plots) as shown in Fig. 4B. The mean StO_2-$ScvO_2$ differences was +15.1 and the standard deviation was 28.6. Thus, the wide limits of agreement between two measures ranged from -13.5 to 43.7. Not all the plot lay between these lines, indicating that the agreement was not satisfactory.

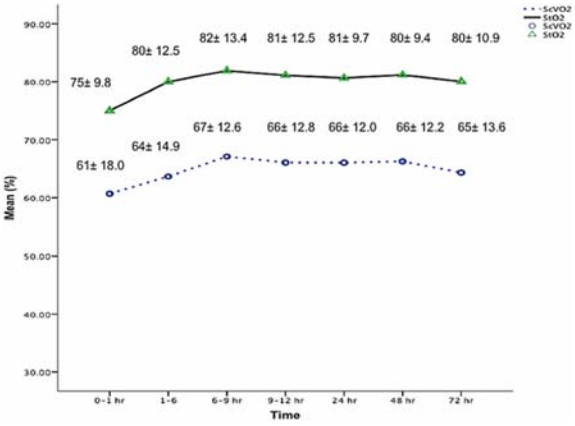
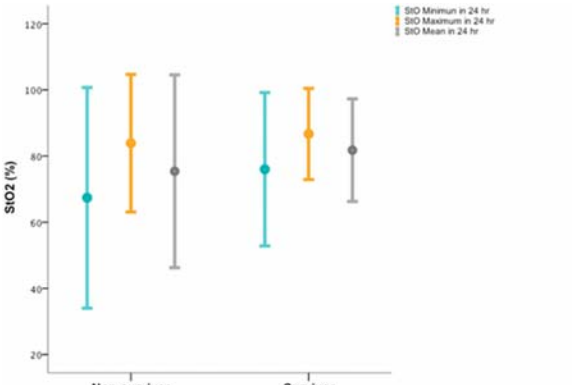


Fig. 1 StO_2 and $ScvO_2$ values during 0-72 hours of septic shock resuscitation.



StO_2 during the first 24 hours	Non-Survivor (% ±SD)	Survivor (% ±SD)	p value
StO_2min	67.4 ± 16.7	83.4 ± 7.8	0.105
StO_2max	83.9 ± 10.3	86.7±6.9	0.379
StO_2mean	74.3 ± 16.0	82.6 ± 9.3	0.016*

Fig. 2 Tissue oxygen saturation in first 24 hours and ICU outcome.

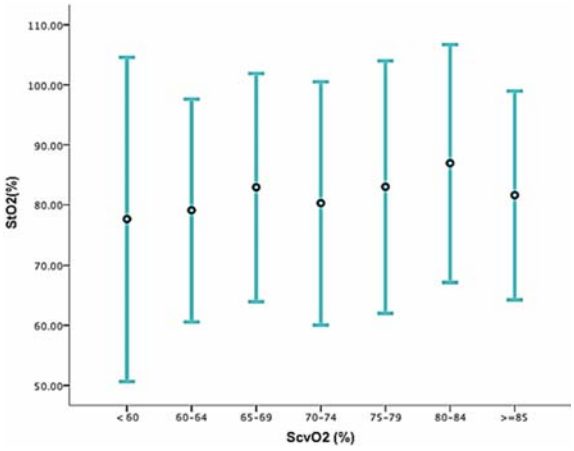


Fig. 3 Tissue oxygen saturation (mean ± SD) in each $ScvO_2$ range.

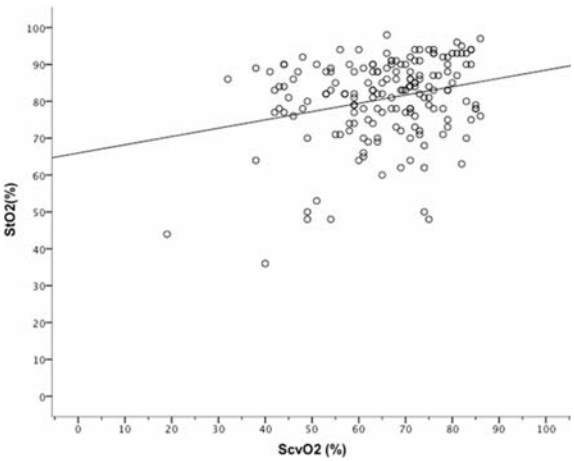


Fig. 4A Correlation between central venous oxygen saturation and mixed venous oxygen saturation (r = 0.253, p<0.001).

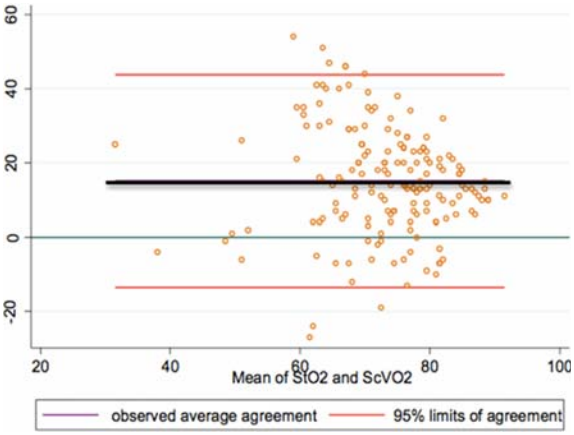


Fig. 4B Plots of absolute differences between StO_2 and $ScvO_2$ against their means according to Bland-Altman. The middle heavy solid line at the middle represents bias (+15.1) and light lines at the top and bottom denote 95% limits of agreement (-13.5 to 43.8).

Discussion

The present study may be summarized that during the first 72 hours of sepsis and septic shock resuscitation, the changes of tissue oxygen saturation (StO_2) and venous oxygen saturation ($ScvO_2$) were in the same direction. Although both values were statistically correlated, the agreement was poor. There was no specific StO_2 value that corresponded to the $ScvO_2$ of 65-75%, the range during which denotes adequate tissue oxygenation. The patients who survived had significantly higher mean StO_2 after reaching the hemodynamic goal than those who died.

Despite the fact that tissue oxygenation monitoring had been introduced for a decade, our study is among the first to demonstrate the dynamics of this parameter as well as those of $ScvO_2$ during sepsis/septic shock resuscitation. Most studies in the past mainly observed the association between single point StO_2 measurement and patients' outcomes[13,14]. This is not practically useful since, in real life, intensivists need certain parameters to state the endpoint of resuscitation after macrocirculation goal is achieved. These parameters must reflect adequate oxygenation or the reversal of tissue hypoxia. At present, $ScvO_2$ and lactate clearance are used[16] and both possess certain limitations. Venous oxygen saturation needs central vein catheterization and serum lactate requires blood sampling and laboratory process. Tissue oxygen monitoring is real time and non-invasive; and, if accurate, could be an effective bedside tool for shock management. As shown in Fig. 1, StO_2 and $ScvO_2$ gradually increased in similar fashion during the first 9 hours, after which they remained stable with an average difference of 15.1%. These findings could be explained from the underlying basis of each study. Venous oxygen is the left over oxygen from tissue respiration, which is low during perfusion deficit, and may be high during prolonged shock[6]. Tissue oxygen saturation obtained by near infrared spectroscopy detects oxyhemoglobin in the microcirculation, which includes arterioles, venules and capillaries of <1 mm size. Thus, certain gradients and some correlation between StO_2 and $ScvO_2$ came from the higher oxygen proportion of StO_2 in microcirculation. Poor agreement between both parameters might be due to the changes in micro-circulation such as vasoconstriction, vasodilatation during sepsis and shock, which influenced StO_2 measurement, and technical artifacts. It was demonstrated that muscle blood flow[17], skin cooling, peripheral vasoconstriction[18], adipose tissue thickness[19,20] had affected NIRS measurement. In addition, altered muscle metabolism such as muscle relaxants and low hemoglobin levels have an effect on this value[21].

The authors found that the average value of StO_2 in the first 24 hours in the surviving patients was higher than in those who died (82.6$\pm$9.3 vs. 74.3$\pm$16.0, $p = 0.016$). However, the cutoff StO_2 value was demonstrated. As noted in Fig. 3, there was no difference in mean StO_2 in each $ScvO_2$ range ($ScvO_2$ <60%, 60-64%, 65-69%, 70-74% 75-79%, 80-84% and >85%). This finding somewhat contrasted to others. Mesquida[11] measured $ScvO_2$ and StO_2 simultaneously after normalization of blood pressures during sepsis resuscitation. Patients with $ScvO_2$ <70% had StO_2 significantly lower than those with $ScvO_2$ >70%. Nardi et al[23] reported a pilot randomized control trial which aimed to investigate the feasibility of targeting StO_2 in addition to the EGDT. They allocated 15 patients each group to EGDT resuscitation with (experimental) or without (control) StO_2. Tissue oxygen saturation was measured over several muscles (masseter, deltoid and pectoral or thenar muscles), and a value of above 80% over at least two muscles was the therapeutic goal. However, the present study was unable to show any difference on clinical endpoints and no clinical benefit of StO_2 was concluded.

From the above data, monitoring StO_2 during shock resuscitation may not be fully useful. However, tissue oxygen saturation increased in the parallel fashion with StO_2, and reached the plateau

simultaneously at the hours 6-9. This makes it evident that both parameters change similarly during resuscitation; and, as a result, the cutoff value concepts should be the same. As noted from our study, $ScvO_2$ of 70% as described in the guidelines is a safe limit to ensure adequate oxygenation. Our postulate which needs further verification is that tissue oxygen saturation of approximately 82% could be used as a cutoff value for adequate tissue oxygenation as well.

The limitation of this study includes the limited number of the patients, which made the study unpowered to judge the clinical efficacy. A central venous catheter was not placed at the beginning of treatment in many patients and so initial information was missed. Studies are in process to determine the diagnostic accuracy of StO_2 as compared with serum lactate clearance to determine the end point of resuscitation.

In conclusion, we report here the temporal changes of StO_2 and $ScvO_2$ during sepsis/septic shock resuscitation. The changes of tissue oxygen saturation and venous oxygen saturation flowed in the same direction, with unsatisfactory correlation. No specific StO_2 value for the reversal of tissue hypoxia was observed. More studies are needed to explore the benefit of StO_2 as a bedside tool for tissue perfusion monitoring.

Potential conflicts of interest

None.

References

1. Spronk PE, Zandstra DF, Ince C. Bench-to-bedside review: sepsis is a disease of the microcirculation. Crit Care 2004; 8: 462-8.
2. Ince C. The microcirculation is the motor of sepsis. Crit Care 2005; 9 (Suppl 4): S13-9.
3. Rivers E, Nguyen B, Havstad S, Ressler J, Muzzin A, Knoblich B, et al. Early goal-directed therapy in the treatment of severe sepsis and septic shock. N Engl J Med 2001; 345: 1368-77.
4. Carlbom DJ, Rubenfeld GD. Barriers to implementing protocol-based sepsis resuscitation in the emergency department—results of a national survey. Crit Care Med 2007; 35: 2525-32.
5. Jones AE, Kline JA. Use of goal-directed therapy for severe sepsis and septic shock in academic emergency departments. Crit Care Med 2005; 33: 1888-9.
6. Permpikul C, Noppakaorattanamanee K, Tongyoo S, Ratanarat R, Poompichet A. Dynamics of central venous oxygen saturation and serum lactate during septic shock resuscitation. J Med Assoc Thai 2013; 96 (Suppl 2): S232-7.
7. Lima A, Bakker J. Noninvasive monitoring of peripheral perfusion. Intensive Care Med 2005; 31: 1316-26.
8. Creteur J. Muscle StO2 in critically ill patients. Curr Opin Crit Care 2008; 14: 361-6.
9. Mesquida J, Espinal C, Gruartmoner G, Masip J, Sabatier C, Baigorri F, et al. Prognostic implications of tissue oxygen saturation in human septic shock. Intensive Care Med 2012; 38: 592-7.
10. Crawford J, Otero R, Rivers E, Goldsmith D. Near infrared spectroscopy as a potential surrogate for mixed venous oxygen saturation for evaluation of patients with hemodynamic derangements. Crit Care 2008; 12(Suppl 2): S69.
11. Mesquida J, Masip J, Gili G, Artigas A, Baigorri F. Thenar oxygen saturation measured by near infrared spectroscopy as a noninvasive predictor of low central venous oxygen saturation in septic patients. Intensive Care Med 2009; 35: 1106-9.
12. Napoli AM, Machan JT, Forcada A, Corl K, Gardiner F. Tissue oxygenation does not predict central venous oxygenation in emergency department patients with severe sepsis and septic shock. Acad Emerg Med 2010; 17: 349-52.
13. Lima A, van Bommel J, Jansen TC, Ince C, Bakker J. Low tissue oxygen saturation at the end of early goal-directed therapy is associated with worse outcome in critically ill patients. Crit Care 2009; 13 (Suppl 5): S13.
14. Creteur J, Carollo T, Soldati G, Buchele G, De Backer D, Vincent JL. The prognostic value of muscle StO2 in septic patients. Intensive Care Med 2007; 33: 1549-56.
15. Levy MM, Fink MP, Marshall JC, Abraham E, Angus D, Cook D, et al. 2001 SCCM/ESICM/ACCP/ATS/SIS International Sepsis Definitions Conference. Crit Care Med 2003; 31: 1250-6.
16. Jones AE, Shapiro NI, Trzeciak S, Arnold RC, Claremont HA, Kline JA. Lactate clearance vs central venous oxygen saturation as goals of early sepsis therapy: a randomized clinical trial. JAMA 2010; 303: 739-46.
17. Davis SL, Fadel PJ, Cui J, Thomas GD, Crandall CG. Skin blood flow influences near-infrared spectroscopy-derived measurements of tissue oxygenation during heat stress. J Appl Physiol (1985) 2006; 100: 221-4.
18. Lima A, van Genderen ME, Klijn E, Bakker J, van

Bommel J. Peripheral vasoconstriction influences thenar oxygen saturation as measured by near-infrared spectroscopy. Intensive Care Med 2012; 38: 606-11.
19. van Beekvelt MC, Borghuis MS, van Engelen BG, Wevers RA, Colier WN. Adipose tissue thickness affects in vivo quantitative near-IR spectroscopy in human skeletal muscle. Clin Sci (Lond) 2001; 101: 21-8.
20. Poeze M. Tissue-oxygenation assessment using near-infrared spectroscopy during severe sepsis: confounding effects of tissue edema on StO2 values. Intensive Care Med 2006; 32: 788-9.
21. Lipcsey M, Woinarski NC, Bellomo R. Near infrared spectroscopy (NIRS) of the thenar eminence in anesthesia and intensive care. Ann Intensive Care 2012; 2: 11.
22. Nardi O, Polito A, Aboab J, Colin G, Maxime V, Clair B, et al. StO, guided early resuscitation in subjects with severe sepsis or septic shock: a pilot randomised trial. J Clin Monit Comput 2013; 27: 215-21.

การเปลี่ยนแปลงของระดับความเข้มข้นของออกซิเจนในเนื้อเยื่อและระดับความเข้มข้นของออกซิเจนในหลอดเลือดดำส่วนกลางระหว่างการรักษาภาวะช็อกจากการติดเชื้อ

ไชยรัตน์ เพิ่มพิกุล, ชุติมา จิระนคร

ภูมิหลัง: *หลักการรักษาภาวะช็อกคือการจัดการให้ออกซิเจนกลับไปเลี้ยงเนื้อเยื่อได้อย่างพอเพียง โดยติดตามจากการตรวจระดับความเข้มข้นของออกซิเจนในหลอดเลือดดำส่วนกลาง (central venous oxygen saturation, $ScvO_2$) หรือการตรวจการลดลงของระดับ serum lactate หลังจากผู้ป่วยมีความดันเลือดกลับสู่เกณฑ์ปรกติการตรวจวัดระดับความเข้มข้นของออกซิเจนในเนื้อเยื่อ (tissue oxygen saturation, StO_2) เป็นวิธีหนึ่งซึ่งอาจใช้ในการติดตามผลการรักษาดังกล่าว*

วัตถุประสงค์: *เพื่อศึกษาการเปลี่ยนแปลงของระดับความเข้มข้นของออกซิเจนในเนื้อเยื่อและระดับความเข้มข้น ของออกซิเจนในหลอดเลือดดำส่วนกลางขณะที่การรักษาภาวะ sepsis และ septic shock ตั้งแต่เริ่มต้นจนถึง 72 ชั่วโมง และเพื่อค่าความสัมพันธ์ระหว่างค่าทั้งสองตลอดจนความเกี่ยวข้องกับผลการรักษา*

วัสดุและวิธีการ: *เป็นการศึกษาไปข้างหน้าในห้องฉุกเฉินและหอผู้ป่วยไอ ซี ยู อายุรศาสตร์ โรงพยาบาลศิริราช ผู้ป่วยที่มีภาวะ sepsis และ septic shock ที่เข้าร่วมการศึกษาจะได้รับการตรวจ $ScvO_2$ และ StO_2 พร้อมกัน ตั้งแต่ชั่วโมงแรกของการรักษา (0-1 ชั่วโมง) จากนั้นจะตรวจวัดเป็นระยะในชั่วโมงที่ 1-6, ชั่วโมงที่ 6-9, ชั่วโมงที่ 12, ชั่วโมงที่ 24, ชั่วโมงที่ 48 และชั่วโมงที่ 72*

ผลการศึกษา: *จากผู้ป่วย 35 ราย ที่เข้าร่วมการศึกษามีการเก็บข้อมูล 170 ครั้ง พบว่าทั้งค่า $ScvO_2$ และ StO_2 เพิ่มขึ้นในลักษณะขนานกัน จากจุดที่เริ่มการรักษาจนถึงจุดสูงสุดที่ชั่วโมงที่ 6-9 จากนั้นคงที่ตลอดการรักษา ค่าทั้งสองมีความสัมพันธ์กันบ้าง ($r = 0.253$, $p = 0.01$) แต่ไม่ไปด้วยกัน ค่าเฉลี่ยของ StO_2 ในช่วง 24 ชั่วโมงแรก สูงกว่าในผู้ที่รอดชีวิต (82.6±9.3 vs. 74.3±16.0, $p = 0.016$) และเมื่อแบ่งกลุ่มผู้ป่วยตามค่า $ScvO_2$ คือ $ScvO_2$ <60%, 60-64%, 65-69%, 70-74%, 75-79%, 80-84% และ >85% พบว่าค่า StO_2 ที่วัดได้กระจายอย่างไม่จำเพาะในแต่ละช่วง*

สรุป: *การศึกษานี้ได้แสดงการเปลี่ยนแปลงของค่า StO_2 และ $ScvO_2$ ระหว่างการรักษาภาวะ sepsis และ septic shock ถึงแม้ว่าค่าทั้งสองจะมีความสัมพันธ์กันบ้างแต่ก็ไม่ไปด้วยกัน การศึกษานี้ไม่สามารถแสดงค่าจำเพาะ (cutoff point) ของ StO_2 สำหรับการพ้นจากภาวะช็อกได้ ผู้ศึกษาเห็นว่าสมควรมีการศึกษาเพิ่มเติมในผู้ป่วยที่มากขึ้น เพื่อตรวจสอบประโยชน์ของการวัด StO_2 ต่อไป*